



DEPARTMENT OF ELECTRICAL ENGINEERING

A STUDY OF 2 GHz REGION ELECTROMAGNETIC PROPAGATION
OVER SELECTED TERRAINS
PROGRESS REPORT FOR THE PERIOD 1 SEPT. 1965 to 1 MARCH 1966

Prepared Under
National Aeronautics and Space Administration
Research Grant NGR 25-001-007

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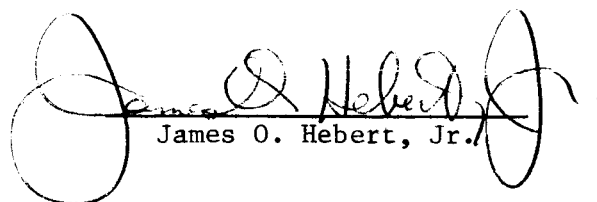
MISSISSIPPI STATE UNIVERSITY
STATE COLLEGE, MISSISSIPPI

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ABSTRACT

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The results for the first six months of research, conducted under NASA Research Grant NGR 25-001-007, to determine propagation reliability in the 2 GHz frequency region are presented. This work has been performed in two phases.

Phase I, the literature survey, has been completed. The results were submitted to the NASA technical monitor for this grant on January 5, 1966. Copies of this literature survey are submitted under separate cover.

In Phase II, the experimental reliability study, the paths to be used have been selected. These paths are part of the Texas Eastern Transmission Corporation 2 GHz microwave system. Instrumentation of all ten paths for signal level distribution analysis has been completed. For the reporting period ending March 15, 1966, approximately twenty percent of the total signal distribution data has been taken. Seventy-five percent of this data has been analyzed. Work is underway for obtaining simultaneous recordings of the receiver AGC signals for three propagation paths. The recorded AGC signals will be cross-correlated to determine if variations in signal strength are due only to changes in local meteorological conditions along the propagation path, as assumed under currently accepted theories of microwave propagation over optical paths.

I. PROJECT OBJECTIVES

The principal objective of this project is to determine the propagation reliability of microwave signals in the 2 GHz frequency region in the Gulf-South Region of the United States. The approach for satisfying this objective consists of two phases.

The objective of Phase I was to review the existing literature on propagation studies in the 2 GHz frequency region. The information from the literature survey served as a guide for planning the experimental program for Phase II.

The objective of Phase II is to determine the fade margins required in order to achieve a particular propagation reliability in the 2 GHz frequency region. This propagation reliability information should be valid for various path lengths in the Gulf-South Region. The fade margin of a microwave link is defined as the ratio (usually expressed in decibels) of the median received signal power to the minimum usable signal power. The median received power is the level of the received power which is exceeded fifty percent of the time. The minimum usable power corresponds to the minimum signal level that the receiver can detect and still maintain a usable output.

Knowledge of the desired fade margin and median received signal allows the sub-systems of the transmitting and receiving station to be determined.

II. PHASE I - LITERATURE SURVEY

A literature survey has been conducted to determine the existing state-of-knowledge of propagation reliability for microwave signals in the frequency range of 1 GHz through visible light. A summary of the literature survey has been published through the Engineering and Industrial Research Station at Mississippi State University.¹ The general conclusions from this literature survey are given below.

There are several points concerning microwave transmission that occur repeatedly in the literature. These main points are:

1. Fading activity is at a minimum during cold weather and at a maximum during hot weather and during night hours. This agrees with the theory that when the air is well mixed, as it usually is during cold, windy, or rainy weather, transmission is usually steady. In the daytime the air is better mixed than during the night hours when cooling results in temperature inversions in the lower layers of the atmosphere.
2. Calm, still air seems to be a condition that promotes stratification and duct formation.
3. Space diversity reception will prove beneficial in reducing fading due to multipath effects.
4. Fades for different frequencies do not often occur simultaneously;

¹"A Summary of Experimental Research On Microwave Propagation Over Optical Paths," Prepared Under NASA Research Grant NGR 25-001-007. January 4, 1966.

hence, frequency diversity should prove beneficial in reducing outages due to fades.

5. There does not seem to be a great deal of difference in the fading characteristics of horizontally and vertically polarized waves.
6. Rainfall attenuation is of little importance for frequencies where wavelengths are 5 cm or more.
7. Signal fluctuations are assumed to be due to atmospheric changes along the propagation path under consideration.
8. There is assumed to be little correlation between the fading occurring over two different paths. However, it is also assumed that the correlation of the yearly statistical averages between two paths having the same length, and lying within the same geographical area is quite high.

Several topics requiring additional study have become apparent from the literature review. These topics are:

1. The effects of different path lengths in the same geographical area on propagation reliability. No serious attempts to derive a relationship between path length and the fading activity have been undertaken. This type of information is important to the communications system designer.
2. The effects of geographical location on propagation reliability. By studying the propagation reliability of similar paths in different geographical areas, the effects of geographical location could be determined.

3. The effects of elevation angle on fading activities for elevation angles in excess of one degree should be determined.

Research conducted on these topics should provide some answers that will lead to methods of predicting propagation reliability of microwave links.

III. PHASE II - EXPERIMENTAL RELIABILITY STUDY

Extensive experimental work for determining propagation characteristics along optical microwave transmission paths has been performed throughout scattered regions in North America. However, only limited and inconclusive experimental work has been carried out for the Gulf-South geographical region. The importance of determining propagation characteristics in this region is made evident by considering the ground link of the communications system for the Apollo program. This communications system will exist over optical paths, some of which have terrain and environmental characteristics quite similar to the Gulf-South area. Propagation reliability has not been determined, by either analytical or experimental methods, for transmission paths in this particular region.

The principal objective of Phase II is to determine the fade margins required for various path lengths in the Gulf-South area in order to achieve a particular propagation reliability in the 2 GHz frequency region. For the experimental phase of the propagation study particular paths in this frequency region and geographical area have been instrumented to obtain propagation reliability information. In the following paragraphs several aspects of the experimental phase are discussed and the current status given.

A. Path Location: The path locations were selected to satisfy the following conditions.

- (a) Different path lengths in the same geographical area.
- (b) Similar path lengths in different geographical areas.
- (c) A path with an elevation angle greater than one degree.

Ten paths of the Texas Eastern Transmission Corporation microwave system were instrumented. This microwave system operates at a frequency of 2 GHz.

Table A gives the location, path length, and operating frequency of nine instrumented paths. These paths are grouped together according to geographical region and thus satisfy condition (a). Three geographical regions are indicated with three paths in each region. The sketch in Figure 1 shows the general geographical regions.

Table B shows the path locations grouped together according to the length of the transmission path. Note that a similar path (with respect to length) exists in each geographical region. This satisfies condition (b) given above.

Table C gives the location, path length, and operating frequency of a single path. The elevation angle of this path is approximately 1.5° and thus satisfies condition (c) above.

| GEOGRAPHICAL REGION | STATION LOCATION | PATH LENGTH (miles) | OPERATING FREQUENCY (GHz) |
|------------------------|-------------------------------------|------------------------|------------------------------|
| A | Hurricane, La. to Dubach, La. | 21.50 | 1.98 |
| | Holly Ridge, La. to Tallula, Miss. | 33.75 | 1.98 |
| | Yazoo City, Miss. to Tallula, Miss. | 40.75 | 1.88 |
| B | Maben, Miss. to Egypt, Miss. | 30.00 | 1.98 |
| | Bexar, Ala. to Egypt, Miss. | 37.50 | 1.88 |
| | Barton, Ala. to Coker, Ala. | 19.50 | 1.98 |
| C | Moreland, Ky. to Elkin, Ky. | 43.50 | 1.98 |
| | Reynoldsville, Ky. to Elkin, Ky. | 31.75 | 1.98 |
| | Garrison, Ky. to Stricklett, Ky. | 21.00 | 1.98 |

Table A. Instrumented Paths Grouped Together According To Geographical Region.

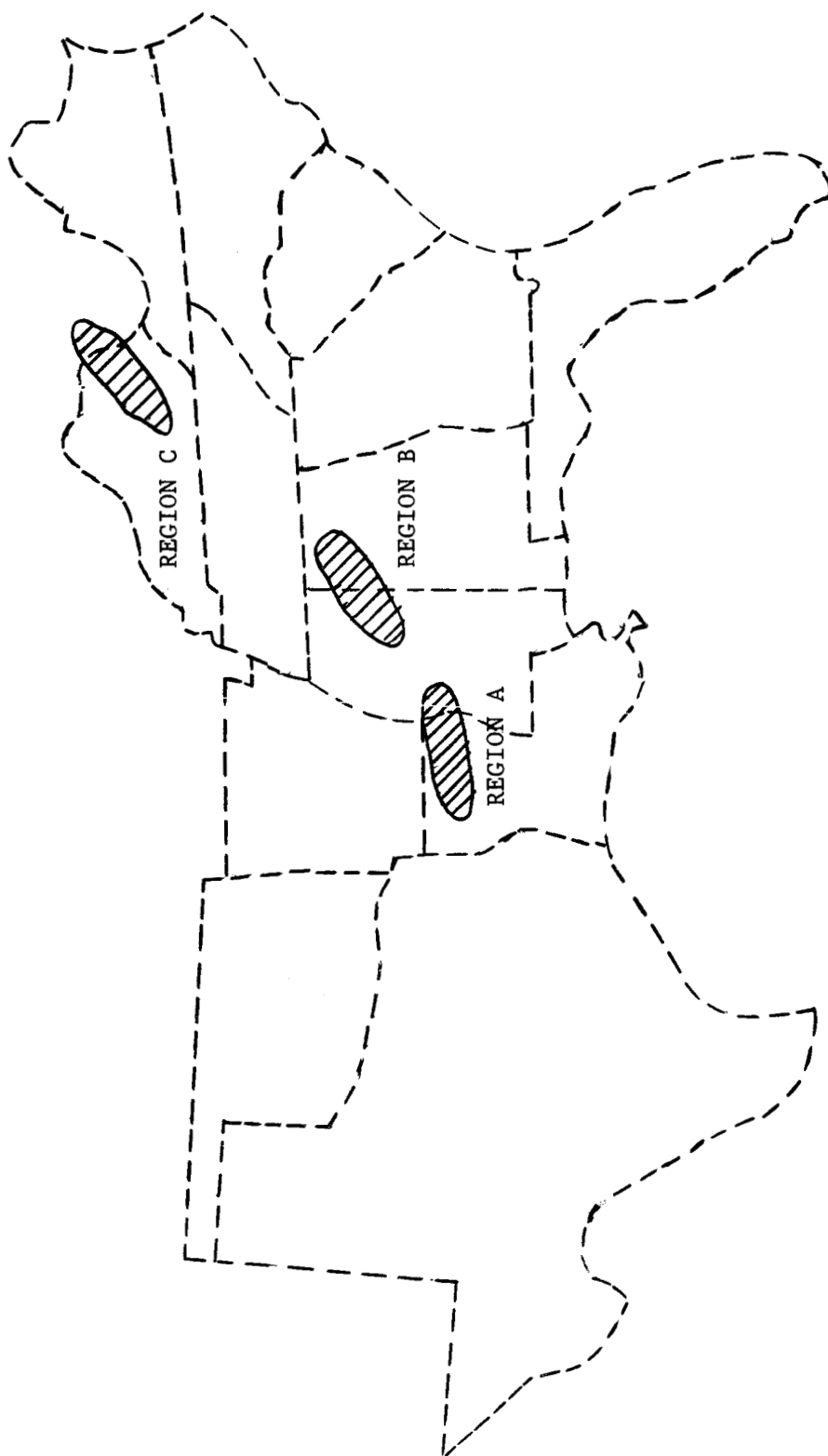


Figure 1. Diagram Showing General Geographical Regions

| STATION LOCATION | PATH LENGTH (miles) | OPERATING FREQUENCY (GHz) |
|-------------------------------------|------------------------|------------------------------|
| Hurricane, La. to Dubach, La. | 21.50 | 1.98 |
| Barton, Ala. to Coker, Ala | 19.50 | 1.98 |
| Garrison, Ky. to Stricklett, Ky. | 21.00 | 1.98 |
| Holly Ridge, La. to Tallula, Miss. | 33.75 | 1.98 |
| Maben, Miss. to Egypt, Miss. | 30.00 | 1.98 |
| Reynoldsville, Ky. to Elkin, Ky. | 31.75 | 1.98 |
| Yazoo City, Miss. to Tallula, Miss. | 40.75 | 1.88 |
| Bexar, Ala. to Egypt, Miss. | 37.50 | 1.88 |
| Moreland, Ky. to Elkin, Ky. | 43.50 | 1.98 |

Table B. Stations Grouped Together According To Path Length.

| STATION LOCATION | PATH LENGTH (miles) | OPERATING FREQUENCY (GHz) |
|-----------------------------------|------------------------|------------------------------|
| Siloam, Ky. to Wheelersbury, Ohio | 3.50 | 1.855 |

Table C. Path With An Elevation Angle of Approximately 1.5 Degrees.

B. Instrumentation: A functional diagram showing the instrumentation for each of the ten stations is given in Figure 2.

The AGC voltage for each monitored receiver is recorded on a Mosely strip chart recorder (Model 680). Calibration of the recorder is accomplished by connecting a Hewlett Packard UHF signal generator (Model 616A) to the input of the receiver and adjusting the recorder sensitivity so that full scale deflection corresponds to a pre-selected input level. The input level is determined by the characteristics of the receiver at a given station. This input level is approximately -35 dbm.

Light sensor diodes (H38) are used to quantize the AGC voltage to correspond to 5 db increments of the input signal. The calibrated output of the signal generator is reduced 45 db from the pre-selected input level, in 5 db steps. A single diode is positioned above each 5 db calibration mark on the Mosely recorder. (The spacing of the diodes will be nonuniform since the AGC signal is nonlinear with respect to the calibrated input signal). A photograph showing the diode units mounted on the Mosely recorder is given in Figure 3.

A metal plate mounted on the Mosely recorder pen will shield the light sensor above the pen from the energizing light source. With the pen in a position corresponding to full-scale deflection, ten elapsed time meters (GE type 236) of the signal distribution analyzer will be activated. As the input signal is lowered by 5 db, the number one photo diode will be energized and will cause elapsed time meter number one to cease operation. Lowering the receiver input signal an additional 5 db will cause photo diode number two to be energized and will deactivate clock number two.

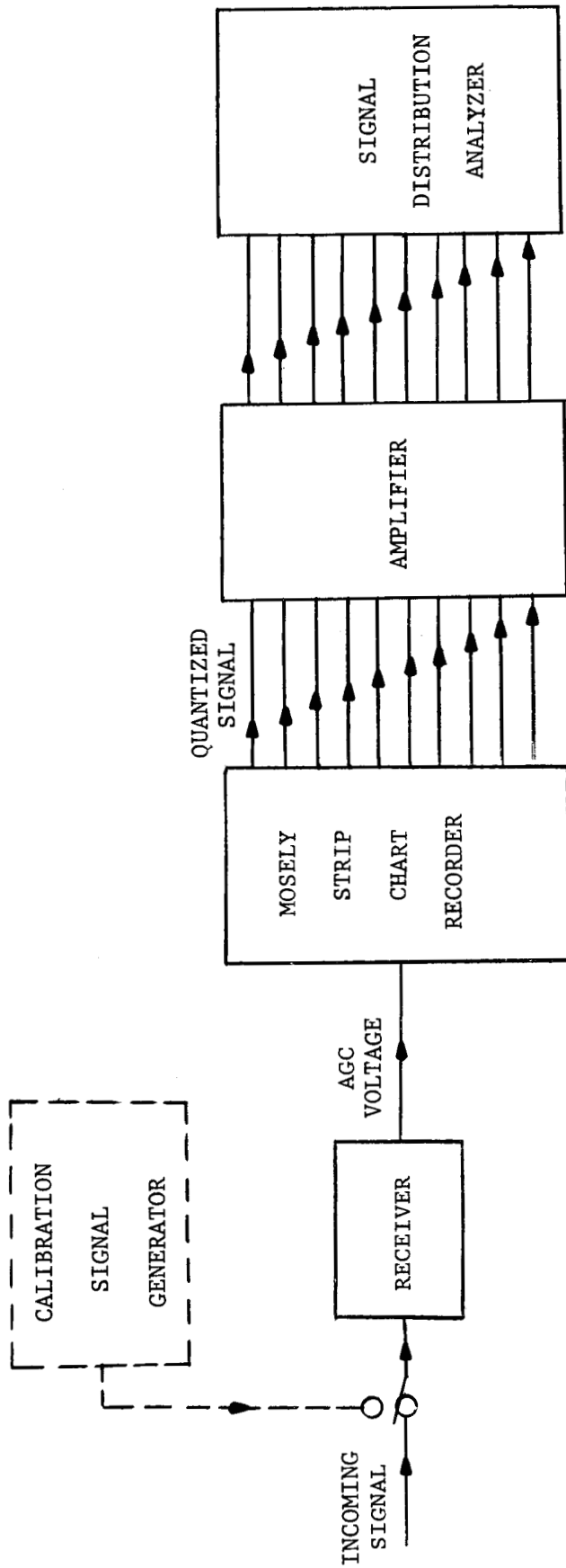


Figure 2. Functional Diagram of Instrumentation System

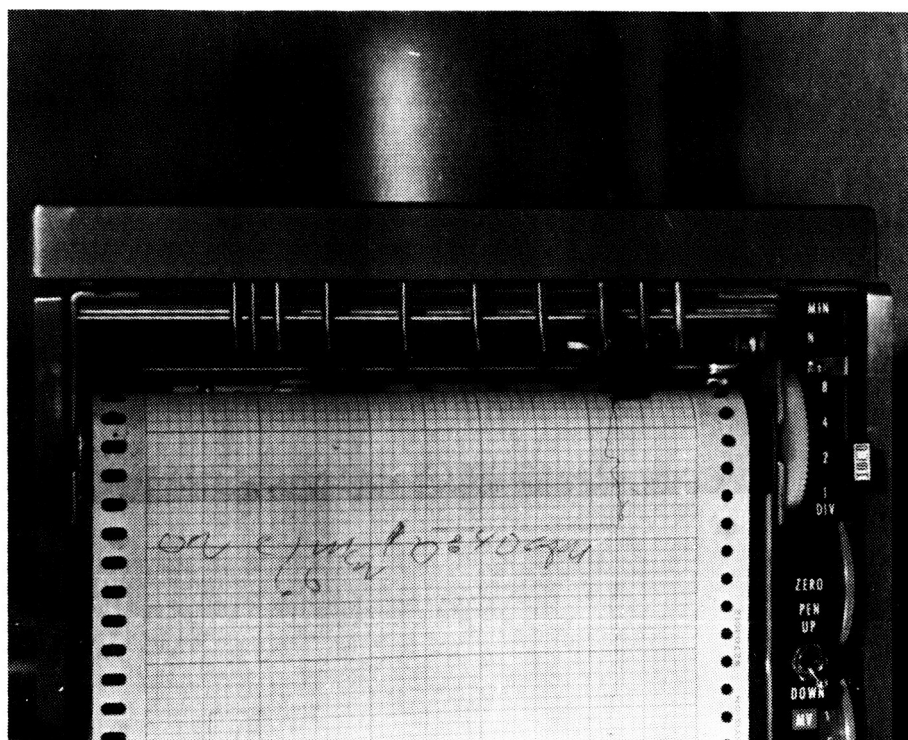


Figure 3. Photograph Showing Diode Units Mounted On Mosely Recorder.

For each additional 5 db decrease of the input signal, an additional clock will be deactivated. A logic circuit prevents the photo diodes corresponding to signal levels below that of the instantaneous received signal level from operating and deactivating their respective clocks.

A photograph of the instrumentation for a typical station is shown in Figure 4. Note that there are eleven clocks mounted on the signal distribution analyzer. The extra clock runs continuously to give the total elapsed time. One additional function of the Mosely recorder is to indicate on the strip chart record when a station receiver has an outage. This outage time must be subtracted from the total elapsed time meter readings.

The eleven elapsed time meters plus an identification data plate are shown mounted on the front panel of the distribution analyzer unit in Figure 4. An automatic camera (Olympus Pen Model EM, 35 mm - 1/2 frame) with an attached timer photographs the panel assembly every six hours.

Each installation is routinely serviced every two weeks. The equipment is checked and calibrated, film and chart paper replaced, etc.

The instrumentation for all ten stations has been completed and installed. All ten stations were completely instrumented and operating properly by February 11, 1966.

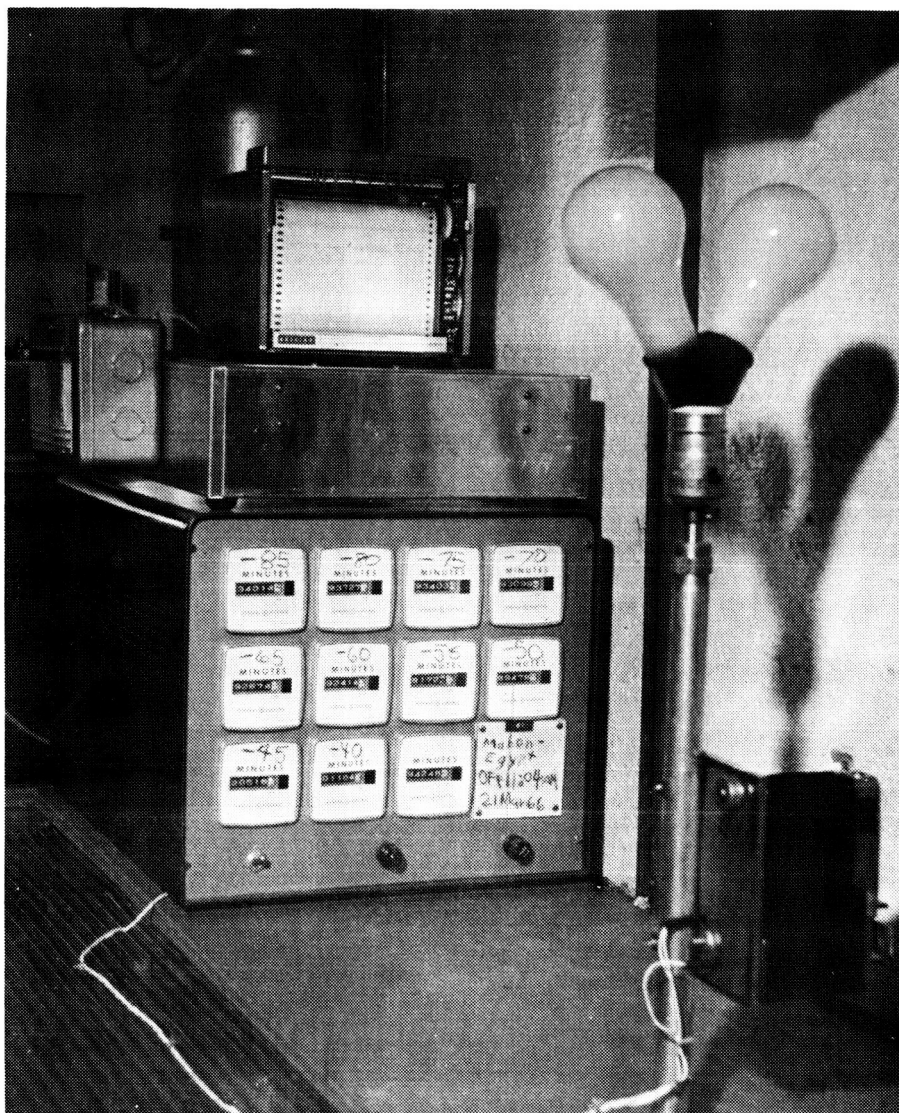
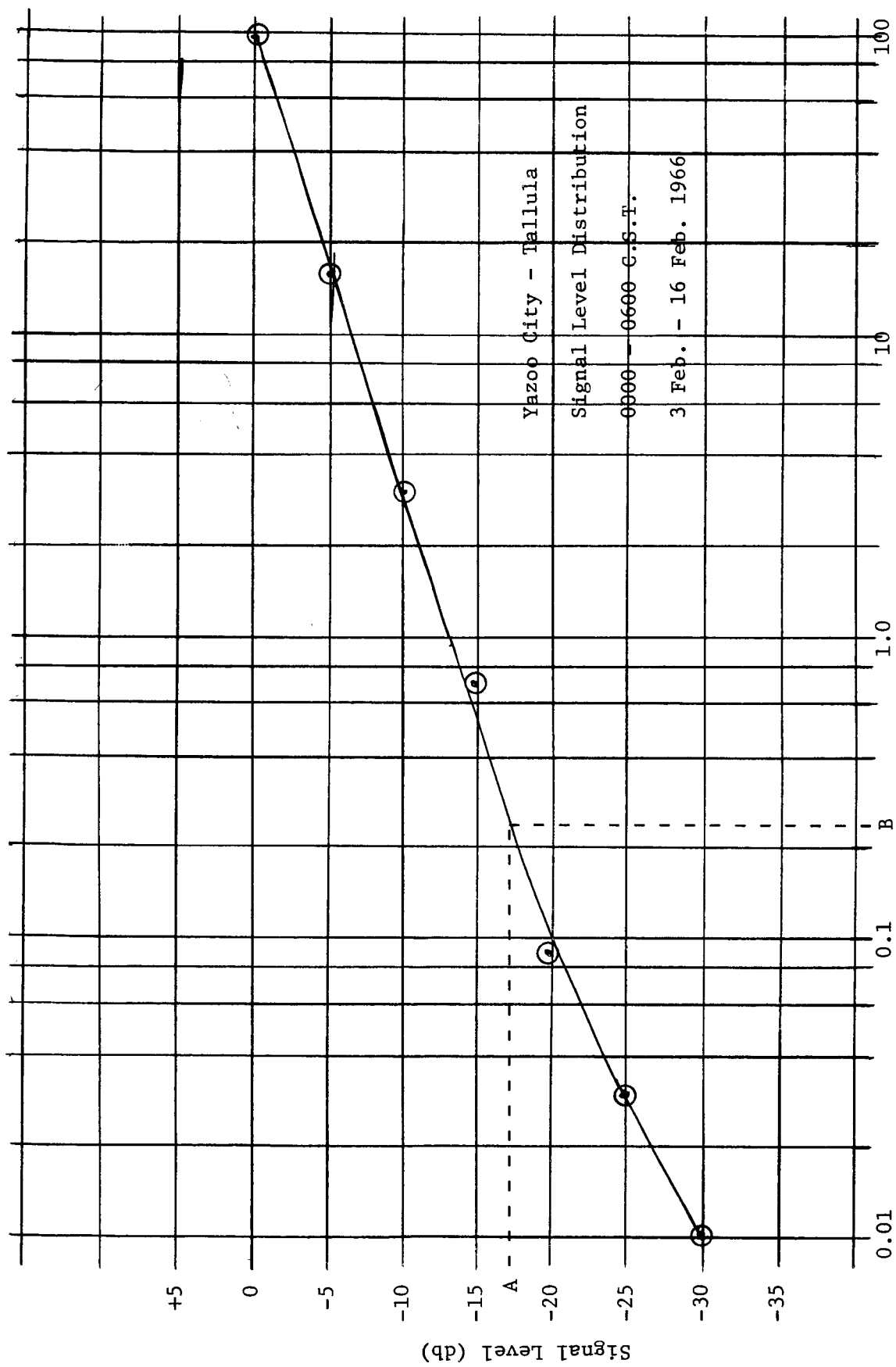


Figure 4. Photograph Showing The Instrumentation For A Typical Station.

C. Data Reducation: The data obtained from the signal distribution analyzer is used to plot the signal distribution curves. A typical curve is shown in Figure 5.

The signal distribution curve is normalized with respect to the receiver AGC voltage. A characteristic curve showing the AGC voltage as a function of the power input to the receiver is shown in Figure 6. As indicated on this curve, there is a particular value of receiver input power for which the AGC voltage drops sharply. This particular value of input power is the maximum usable signal power for the receiver. In normal operation, the received signal never reaches this level. The maximum calibration value is normalized to zero db for plotting the signal distribution curve. The ordinate of the distribution curve is thus the level (in db) that the received signal is below the maximum calibration level. The abscissa of the distribution curve is the percent time of the total reporting interval. The time interval considered can be hours, days, weeks, or months. The coordinate points, A and B, shown on the distribution curve of Figure 5 should be interpreted to mean that the signal level was equal to or less than A db for B percent of the time.



Percent Time Signal Was Below Ordinate Value

Figure 5. Typical Signal Level Distribution Curve

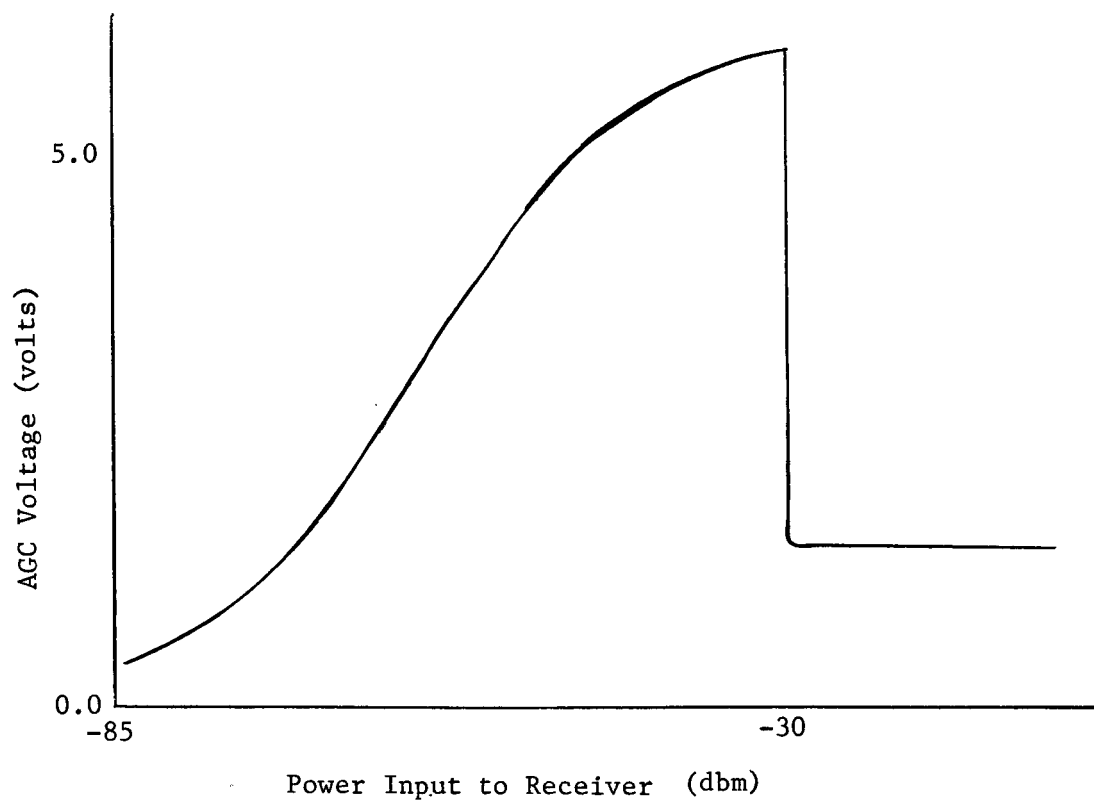


Figure 6. A General AGC Voltage Characteristic Curve

Signal level distribution curves are plotted for each of the ten selected paths. The data for each distribution curve represents a fourteen day recording period. Curves will also be plotted for each path on a monthly and semi-annual basis.

For the reporting period ending March 15, 1966, approximately twenty percent of the total signal distribution data has been taken. Seventy-five percent of this data has been analyzed.

D. Additional Analysis: Work is underway for obtaining simultaneous recordings of the AGC signals for the three paths in geographical region B. These signals will be recorded on an Ampex SP-300 Instrumentation Recorder. The recorded AGC signals will be cross-correlated.

The generally held theory governing propagation reliability is that the variations in signal strength are due to changes in local meteorological conditions along the propagation path. If there is any major degree of correlation between the fluctuations of the signals during periods of fading activity, as determined by the present study, the generally held theory must be reconsidered. Other than visual observations of strip chart records, published data has not been found which pertains to cross-correlation for different propagation paths.